Remarks

Further and favorable reconsideration is respectfully requested in view of the foregoing amendments and following remarks.

Thus, claims 4 and 7-11 have been cancelled, and claims 1 and 3 have been amended.

The amendments to claim 1 are supported by the last two paragraphs on page 4 of the specification. Thus, amended claim 1 recites an energy efficient method for recovering substantially all carbon dioxide generating in a combustion process which includes application of sweep gas in combination with a mixed conducting membrane. Step c) indicates that the sweep gas picks up oxygen on the permeate side of a second mixed conducting membrane in a second stage downstream the combuster in step b) which is capable of separating oxygen from a pre-heated air stream fed to the retentate side of the second membrane. Step d) then recites that the concentration of oxygen in the sweep gas of step c) is increased in the second membrane to a sufficiently high level to be used as oxidant in the combuster in the second stage to which a carbon containing fuel is separately fed and combusted.

Claim 3 has been amended to recite that the sweep gas in step a) is superheated stem or a mixture of steam and recycled exhaust gas.

New claims 13 and 14 have been added to the application. Claim 13 is supported by page 5, lines 8-11, and claim 14 is supported by the last two paragraphs on page 10.

The rejection of claim 1 under the second paragraph of 35 U.S.C. §112 for the reason set forth in the previous Office Action is respectfully traversed.

Considering the first full paragraph on page 3 of the Office Action, Applicants take this rejection to be limited to the question of how the concentration of oxygen relates to its inherent oxidizing ability and what levels are thus excluded.

However, it is unclear why claim 1 is indefinite for failure to recite how the concentration of oxygen relates to its inherent oxidizing ability, or what levels are thus excluded. Rejection based on indefiniteness implies that one of ordinary skill in the art would not be able to determine the subject matter on which a claim reads. The steps recited in amended claim 1 are sufficiently clear to enable the art-skilled to make this determination. For instance, step d) recites that the concentration of

oxygen in the sweep gas of step c) is increased to a sufficiently high level to be used as oxidant in the combuster in the second stage to which a carbon containing fuel is separately fed and combusted. The use of such functional language is appropriate as a way of reciting the level of the concentration of oxygen.

For these reasons, Applicants respectfully submit that the rejection of claim 1 under the second paragraph of 35 U.S.C. §112 should be withdrawn.

The patentability of the present invention over the disclosures of the references relied upon by the Examiner in rejecting the claims will be apparent upon consideration of the following remarks.

The main object of the present invention was to arrive at an energy efficient method for recovering substantially all CO_2 generated in a combustion process. This object is fulfilled by the present method which includes an efficient application of a sweep gas in combination with a mixed conducting membrane. In order to obtain an efficient application of sweep gas in combination with a mixed conducting membrane the inventors found that by using a method according to the present claims, the amount of sweep gas necessary for production of a given amount of oxygen will be reduced and thus the size of equipment necessary for producing sweep gas to the first mixed conducting membrane stage will be reduced. Application of e.g. 10 stages will reduce the amount of sweep gas with about 95 % compared with a single stage process and reduce the energy required to generate sweep gas in the same order of magnitude.

Thus, an energy efficient method for recovering substantially all CO_2 generated in a combustion process is achieved by application of a multi staged method.

The rejection of claim 7 under 35 U.S.C. §103(a) as being unpatentable over Prasad et al. (USP 5,888,272) in view of Prasad et al. (USP 5,976,223), as well as the rejection of claims 7-11 under 35 U.S.C. §103(a) as being unpatentable over Prasad et al. (USP 5,888,272), have been rendered moot in view of the cancellation of these claims.

The rejection of claims 1 and 3-5 under 35 U.S.C. §102(e) as being anticipated by Prasad et al. (USP 5,888,272), as well as the rejection of claim 12 under 35 U.S.C. §102(e) or 35 U.S.C. §103(a) based on this reference, the rejection of claim 6 under 35 U.S.C. §103(a) as being

unpatentable over this reference, and the rejection of claim 2 under 35 U.S.C. §103(a) as being unpatentable over this reference, are respectfully traversed.

At the outset, Applicants note that Prasad et al. '272 does not describe a multi stage method for reducing the sweep gas demand to obtain an energy efficient method for recovering substantially all CO_2 generated in a combustion process.

In general, the object of the reference was to provide an efficient integrated process for oxygen-enhanced combustion, while the object of the present invention was to arrive at an energy efficient method to recover substantially all CO_2 generated in a combustion process. This difference is clearly shown in that the oxygen depleted air stream and the CO_2 containing stream in most cases in Prasad et al. are mixed downstream the membrane. In this case it will not be possible to recover CO_2 in an efficient way. Otherwise, if the two streams are not mixed, the objective of the reference is to produce a nitrogen-enhanced gas stream, and not CO_2.

The present state of the art techniques as disclosed in Prasad et al. use large amounts of recycled exhaust gas to purge the permeate side of the membrane. The present invention, however, will reduce the required amount of purge (or sweep gas) gas significantly to obtain an energy efficient method for recovering CO_2. This is obtained by using several stages where each stage includes a membrane, a combustor and a combustion chamber. Application of e.g. 10 stages may reduce the amount of sweep gas with about 95 % compared with a single stage process as disclosed in Prasad et al. This has several advantages:

The staged process can operate at a low (< 10 %) concentration of oxygen in the oxygen-enriched sweep gas improving the driving force for oxygen transport through the membrane. This will reduce the membrane area and thus the costs.

The amount of sweep gas (or recycled combustion gas) is significantly reduced. If exhaust gas is recycled, a blower or a compressor device is needed to circulate the purge gas (i.e. to overcome the pressure drop in the cycle). Due to the high temperature of recycled gas (400 - 1100°C) this compressor device could be very expensive and the energy requirement to recycle the gas could by the same reason be rather high. By reducing the amount of recycled gas both the cost and energy requirement will be significantly reduced.

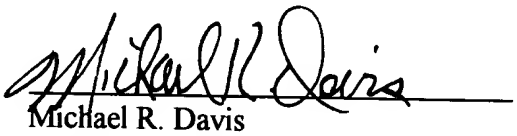
Furthermore, the main object of Prasad et al. is production of enriched oxygen streams with a rather high concentration of oxygen (10-90 %). Use of multiple steps with combustion and heating of air has no advantage in this case. The advantages of the present staged technique, however, are production of a gas stream with a low concentration of oxygen to avoid excessive heat generation in the combustion sections, and to improve the driving force for oxygen transport. The driving force for oxygen transport through the membrane decreases with increased oxygen concentration in the sweep gas.

For these reasons, Applicants take the position that the rejections based on Prasad et al. '272 should be withdrawn.

Therefore, in view of the foregoing amendments and remarks, it is submitted that each of the grounds of objection and rejection set forth by the Examiner has been overcome, and that the application is in condition for allowance. Such allowance is solicited.

Respectfully submitted,

Knut Ingvar ÅSEN et al.

By: 

Michael R. Davis
Registration No. 25,134
Attorney for Applicants

MRD/pth
Washington, D.C. 20006-1021
Telephone (202) 721-8200
Facsimile (202) 721-8250
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